Art. III. — *The United States Exploring Expedition. Geology:* By James D. Dana, Geologist of the Expedition. Large 4to. pp. 746. With an Atlas of 21 Plates in folio. New York.

Ten years have elapsed since "The United States Exploring Expedition" returned to our shores; but the publication of the results of its comprehensive and thorough survey of the remotest bounds of the earth is not yet completed. The volume now before us is one of the latest that have appeared, and is certainly not the least important and interesting of the whole series. The wisdom of Congress having limited the printed edition of these invaluable scientific reports to *one hundred copies*, so that, for most practical purposes, they are not published at all, we have endeavored, from time to time, when we could get possession of a copy, to give our readers some account of its contents, being satisfied that they would otherwise have little chance of learning any thing about them. Before considering the results of Mr. Dana's geological investigations, let us briefly survey the field of his labors, that we may form some idea of its magnitude, and of the opportunities afforded him for observation.

The Expedition, which sailed from Norfolk in August, 1838, first made its way to the island of Madeira, a region made classic ground to the geologist by the researches of Von Buch; thence it proceeded to Rio Janeiro, and, after making some stay there, and at the Rio Negro, to Nassau Bay, Terra del Fuego. Here the scientific corps were left to make observations in the vicinity of the Straits of Magellan, during the southern cruise of Captain Wilkes. After his return, the Expedition proceeded to Valparaiso, whence excursions were made to the Cordilleras, and to the mines in the vicinity. Thence the little fleet sailed to Callao, from which point some of the scientific gentlemen visited the Cordilleras, while Mr. Dana was engaged in examining the coast in that neighborhood. From Callao a nearly straight course was made for the Paumotu group of islands; and after the lapse of about one year from the time of leaving home, the first coral island, Clermont de Tonnerre, was seen. Here opened a rich field for investigation, and abundant opportunities for exploration were afforded

to the scientific corps, while the surveying and hydrographical parties were engaged in this group, in the Society Islands, and the Samoan archipelago. After several months spent among the coral islands, the vessels proceeded to Port Jackson, New South Wales, where they were to refit and prepare for another cruise in search of an unknown continent to the south, while the *savans* were left to examine the neighborhood of Sydney, and thence to make their way to New Zealand. After the return of the Expedition from the eminently successful southern cruise, their course was again turned to the island groups of the Pacific. Leaving the Bay of Islands, on the 6th of April, 1840, the Friendly, Fegee, Samoan, Kingsmill, and Hawaiian groups were successively explored during the next year. The Vincennes left the Hawaiian islands on the 5th of April, 1841, for the Columbia river; while the Peacock, to which Mr. Dana was attached, was engaged in farther investigations among the Samoan, Ellices, and Kingsmill groups. After being occupied here for some months, the vessel made the mouth of the Columbia river on the 17th of July, and was wrecked on the bar; by which sad accident, though luckily unattended with loss of life, a valuable portion of the collections was destroyed. From the Columbia river, a party, of which Mr. Dana was one, made its way by land to San Francisco, where they joined the Vincennes on the 24th of October. From the last-mentioned place, the Expedition traversed the Pacific to Manilla, where, as well as in the Sooloo sea, extended observations were made. Thence the fleet, now reduced to the Vincennes and the Oregon, a ship chartered at Vancouvre, made its way home by the Cape of Good Hope and St. Helena, arriving at New York on the 10th of June, 1842, after an absence of nearly four years.

This sketch of the route traversed by the Expedition will be sufficient to show what an extensive field was opened for research to a corps of enthusiastic explorers. Though, from the nature of the Expedition and its multifarious objects, they could not always command as much time as they desired at those points which appeared to them the most interesting, still the whole course seems to have been judiciously planned and consistently carried out.

The great field of exploration was the Pacific Ocean, that

magnificent waste of waters, covering more than three tenths of the surface of the globe. The islands which dot its surface, though nearly seven hundred in number, would form, if all were brought together, but a mere speck in the vast ocean through which they are actually distributed. Yet, as Mr. Dana remarks, —

"This small area of land presents us with mountains 14,000 feet in height; volcanoes of unrivalled magnitude; peaks, crags, and gorges of Alpine boldness. And amid the wildness and grandeur of these scenes, many of which would well aid our conceptions of a world in ruins, the palm, the tree-fern, and other tropical productions flourish with singular luxuriance. Zoöphytes, moreover, spread the sea bottom near the shores with flowers, and form islands with groves of verdure above, and coral gardens beneath, the water. There is no part of the world where rocks, waterfalls, and foliage are displayed in greater variety, or where the sublime and the picturesque mingle in stranger combinations."

After a few general remarks on the topography of the Pacific, and, especially, the distribution of the islands over its surface, in which he recognizes two great general directions of trend, nearly at right angles to each other, the discussion of the theoretical bearing of which important fact he defers to a later chapter, the author gives a general sketch of the geological constitution of the islands of the Pacific. These are divided into two great classes, the coral and the volcanic; and to one or the other of these belong all Polynesia, excepting New Zealand, Micronesia, and a considerable portion of Melanesia. It is not till we approach the East Indies and Asia, that the islands begin to assume a continental character. In New Zealand, we find granite, slates, and coal; while many of the larger islands of Melanesia resemble, in geological character, Australia and New Guinea. The two great topics, therefore, are the coral formations and the phenomena of volcanoes.

The history of investigation and discovery with regard to the coral islands of the Pacific forms one of the most striking and interesting chapters in the records of geological research. The first description of them was given by Forster, who accompanied Cook on his second voyage, though their remarkable structure had been alluded to by Pyrard de Laval

as early as 1605. The Pacific has been so often visited and described since that time, that, as Mr. Dana remarks, in speaking of the coral islands, "their general features are probably almost as familiar to the reader as the scenes of the lands around us." Yet it was not till within a very few years that a satisfactory theory was framed to account for all the phenomena presented by the various forms of these islands, in connection with the known habits of the coral-forming animals.

Forster, whose observations were published in 1783, and afterwards Flinders, Péron, and others, supposed that the coral-building animals commenced their work at the bottom of the ocean, without regard to its depth, and carried up gigantic walls to the surface. To account for the peculiar form of the *atolls*, or ring-shaped islands inclosing a lagoon, Forster conceived that the coral animals were endowed with a peculiar instinct, by which they were led to build so as to inclose a circular space, within which they might live protected from the action of the waves. This hypothesis, although very generally received for a time, was, on a more careful investigation, found to be wholly untenable. Farther and more careful researches, and especially those of Quoy and Gaimard, who accompanied Captain Freycinet and afterwards Captain Duperrey, and of Darwin, who was attached to the expedition of Captain Fitzroy in the Adventure and the Beagle, proved most satisfactorily, that the coral animals, and especially those which are the principal reef-builders, are rarely found alive at a depth greater than from twenty to thirty fathoms. This fact has been abundantly confirmed; and it is remarked by Mr. Dana, that the observations and extensive soundings of the Expedition show that there is no evidence of growing corals below twenty fathoms. It will at once be seen that this fact must be taken into consideration in any theory of the coral islands, and that it completely demolishes the old hypothesis of Forster. Besides, why should the same animals build only atolls, or annular-shaped islands, in certain regions of the Pacific and Indian oceans, and everywhere else only simple reefs? How can we conceive of a common instinct giving the same plan of action to animals belonging to so many different genera and species, and whose accumulated work is the result of a mere secretive process, not by any means to be compared to that of the bee, which, under the direction of a mechanical

instinct, may truly be said to *build* its cells? Moreover, the idea that quiet water was advantageous or necessary to the growth or protection of the coral animals was quite erroneous. It is now known, that those species which contribute most to the formation of the reefs flourish best in the open ocean, where they are exposed to the full force of the breakers; while the turbid water of the small lagoons is injurious to their development. They require the pure ocean water; and, as they cannot leave their places to search for their food, it must be brought to them by the ceaseless motion of the waves. From all these considerations, it will be seen how unsatisfactory and contrary to the facts was the old theory of the coral islands.

Another hypothesis was first proposed by Steffens, and especially advocated by Lyell, according to which it was assumed that each of the annular accumulations of coral was built up on the rim of the crater of a submarine volcano. Many circumstances seemed to render this view, at first sight, a highly probable one. There are many active volcanoes in the coral region of the Pacific; and numerous volcanic cones, which rise above the water in different parts of the world, are found to have a remarkable analogy of form with the atoll;—for instance, those of Santorin. It was a serious objection to this theory, however, that it required us to believe in the existence of craters sometimes thirty, fifty, or even ninety, miles in diameter, that being the size of some of the atolls; while the largest crater in the world, as far as we know, namely, that of Mokua-weo-weo, the summit crater of Mount Loa, is only two and a half miles in its largest diameter. The fact that all these islands are nearly at the same level, namely,—that of the water,—did not excite surprise, since it was supposed that the coral animals had built up from the submarine volcanic crater, at whatever depth it might be. But, now when we know that these animals cannot live at a greater depth than two hundred feet, at the most, if we adopt this theory, we shall be required to believe that hundreds of volcanic craters arose, within a comparatively small space, to almost exactly the same height, none of them being elevated above the water; which would be contrary to all analogy of what we know of subaerial chains of mountains. Besides, as reefs of dead coral are found at great depths below the sur-

face, it would still be necessary to explain their formation below the line at which the animals by which they were formed must have lived.

This was the state of opinions with regard to the formation of the coral islands, when Mr. Darwin gave to the world his beautiful theory, which so harmoniously links together all the facts, and connects the work of microscopic animals with the great secular changes in the form of the globe itself. To form an idea of this theory, let us conceive of an elevated island within the coral region, which, at the distance and within the space suited to their growth, the coral animals have encircled with a reef. If we suppose the relative level of land and water to remain the same, after a certain period there can be no farther perceptible change in the relative position of the reef and island; the former will remain as a low platform of rock encircling the island, such as is now called a *fringing reef;* since the animals cannot build above the water, nor can they enlarge the base of the structure by extending it into the deeper water beyond its present exterior limits. But now, if we conceive that the island begins gradually to sink, the coral animals will be able to continue their work, being still under water, and to build up at a rate commensurate with the amount of subsidence. It is easy to see, then, that the thickness of the coral will be limited only by the rate and amount of the vertical depression of the base on which the whole superstructure stands. Thus, at different stages of its formation, the coral island will pass from a lofty and precipitous, generally volcanic, island with a fringe of coral, to a central mass with both a fringing and a barrier reef, the latter being the term used to denote a reef encircling the island at some distance from the land; and, finally, when the subsidence has gone so far that the original island has entirely disappeared beneath the waters, there will remain an atoll, or a circular reef, more or less rudely shaped, inclosing a lagoon which marks the site of the drowned island. All of these various forms are found in the limits of the Pacific, and they thus indicate the relative amount of subsidence of the different regions in which they predominate.

It may perhaps be asked, by way of objection to the subsidence theory of Darwin, as it is frequently called, why it is, that, as the island sinks, the space between the coral reef

and the land does not become filled with the growing coral, so as to form a solid plane of coral rock, instead of a ring. It was the opinion of Darwin that this greater increase on the exterior of the reef was due principally to the circumstance that the more rapidly-building species flourish best where they are exposed to the action of the surf. Mr. Dana has well illustrated this point.

"It has been shown that the ocean acts an important part in reef-making; — that the outer reefs, exposed to its action and to its pure waters, grow more rapidly than those within, which are under the influence of marine and fresh-water currents and transported detritus. It is obvious, therefore, that the former may retain themselves at the surface, when, through a too rapid subsidence, the inner patches would disappear. Moreover, after the barrier is once begun, it has growing corals on both its inner and outer margin, while a fringing reef grows only on one margin. Again, the detritus of the outer reefs is, to a great extent, thrown back upon itself by the sea without and the currents within, while the inner reefs contribute a large proportion of their material to the wide channels between them. . . . Owing to these causes, the rate of growth of the barrier may be at least twice more rapid than that of the inner reefs. If the barrier increases twenty feet in height in a century, the inner reef, according to this supposition, would increase but ten feet; and any rate of subsidence between the two mentioned, would sink the inner reefs more rapidly than they could grow, and cause them to disappear. A wide, flat reef, continuous over such extensive reef-grounds, could only be formed with an extremely slow rate of subsidence; and, even then, they would be liable to be cut up by the production of inner currents, destroying growing corals over the interior parts of the coral reef; so that, whatever the rate of subsidence, the inner portions would grow less rapidly."

The general result of Mr. Dana's labors is to prove, most satisfactorily, that the theory of Darwin affords the only satisfactory explanation of all the phenomena of the coral islands, and that it must be received by the geologist and allowed its proper weight in the theoretical discussion of the great secular changes of the globe. It is in this application, that the researches and theoretical views of Mr. Dana are of great importance; but they are deferred by him till after a description of the volcanic phenomena, with which they are so intimately connected.

The distribution of the coral reefs and islands over the surface of the globe is a matter of much interest, and Mr. Darwin had called attention to it as a subject but imperfectly understood. When we look at a chart of the globe on which the coral accumulations are represented, there seems to be a striking want of regularity in their distribution. Thus, we find the whole of the west coast of South America entirely destitute of coral reefs; the same is true of the China sea, and of the coast of Asia bordering on the Indian Ocean. Mr. Dana has discussed this subject with his usual ability, and though his investigations do not clear up all the difficulties, yet they indicate the general causes by which the distribution of the growing coral has been affected. The first and most important circumstance is the temperature of the ocean. From a comparison of numerous thermometrical observations, Mr. Dana has arrived at the conclusion that the coral animals may flourish when the winter temperature does not fall below 66°; and he has drawn upon the chart accompanying his work the boundary of the coral region. From this chart it will be seen, that the width of the coral-reef seas is very variable. It extends over sixty-four degrees of latitude on the Asiatic side of the Pacific, and over only seventeen on the American coast. Besides temperature, the character of the coast has an important influence in modifying or repressing entirely the growth of coral. Thus, if there are rivers bringing down detritus to the sea, and rendering the water turbid and muddy, there can be no coral reefs. So, also, the influence of volcanic agencies in the planting and increase of reefs is abundantly exemplified; and various instances are referred to where submarine eruptions, or heating of the ocean water by volcanic causes, have destroyed the coral reefs or prevented their formation.

It is curious to trace the gradual progress of the coral reef, as it undergoes the necessary changes which are to render it habitable; though it must be confessed that the coral island, however poetical its origin may be supposed to be, is, at best, but a sorry habitation for man. Since the coral animal does not carry up his work above the level of low tide, how is the reef raised above the surface, so that man can find a foothold upon it? The principal agent in this work is the never-ceasing action of the waves, which, dashing against the outer

edge of the reef, gradually dislodge and pile up huge masses of the coral-rock, till the general level becomes, at last, raised above the level of any but the highest tides. The fragments are gradually worn down into a calcareous sand or mud, and are thus carried by the waves, or blown by the wind, and lodged in the crevices of the detrital rock. Calcareous water, filtering through, cements the whole together into a coherent mass. Seeds washed up by the waves, or dropped by birds, are scattered over the surface; and soon the apparently barren plain is covered with verdure. Sometimes a log drifts to the shore; and we learn from Mr. Dana, that such a waif is, on some of the more isolated atolls, considered a direct gift of a propitiated deity. The inhabitants of these islands are never in secure possession of their homes, being always liable to be washed off by heavy storms; for, as their land rises, at most, no more than ten or twelve feet above the sea, it is easily overtopped by the highest waves. A still more terrible devastation is probably sometimes caused by the great earthquake waves, such as have swept the coast of Peru and Chili, and which, rolling over these low islands, would leave not a vestige of man or his works behind them. During the heavier gales, the houses are sometimes tied up to a tree, or to a stake driven into the ground, that they may not be swept away. The cocoa-nut, "the tree of a thousand uses," and the fish easily captured among the reefs, form almost the entire resources of the inhabitants. The number of human beings who succeed in finding the means of living under such circumstances, is very considerable; as we are informed by Mr. Dana, the island of Tapouteouca, the whole habitable area of which does not exceed six square miles, supports a population of 10,000 persons.

Some of the geological applications of the observations among the coral islands, made by Mr. Dana, are of great practical interest. One of the most striking facts mentioned by him is the way in which the coral reef-rock is gradually converted into a solid, compact, homogeneous limestone, often entirely destitute of every appearance of its organic origin. The coral reef has lost its original character over a great portion of its surface, and it is only its exterior which is the proper growth of the living reef. The comparative scarcity of embedded fossils is another interesting fact of the

same character; though formed in the midst of seas swarming with animal life, the coral rock seems, in general, to contain hardly a trace of the remains of organized beings. This is, however, the necessary result of the unceasing grinding action of the waves, by which every thing is reduced to powder, thrown up, and carried inward upon the reef, or spread in strata upon the floor of the ocean. Hence, as Mr. Dana remarks, we cannot be too careful in inferring, from the comparative absence of fossils in any set of strata, that they were deposited in a sea in which nothing organic was living.

The common reef corals consist almost entirely of carbonate of lime; they contain from 90 to 96 per cent. of this constituent. The remainder is principally organic matter, together with one or two per cent. of earthy ingredients, consisting principally of silica, oxide of iron, and phosphates and fluorides of the earthy bases. There is hardly more than a trace of carbonate of magnesia in the growing coral; yet, according to the analysis of Mr. B. Silliman, Jr., some specimens of the coral rock contain a large per centage of this salt. An analysis is given of a specimen of the coral-limestone of the island Matea, in which, according to his authority, 38 per cent. of carbonate of magnesia is contained. This is a highly important fact, and we wish to see it confirmed by other analyses; especially as, in the one given, the magnesia seems to have been determined from the loss.

Besides the phenomena of the coral reefs and islands, there is another field of geological research opened in the islands of the Pacific, which our author has cultivated with equal zeal, and of which the highly interesting results form the second division of his work. We refer to the volcanic agencies exemplified on so grand a scale in that region, which are of especial interest on account of their intimate connection with those greater phenomena of elevation and subsidence, which have given form and outline to the principal features of the earth's surface. The high islands of the Pacific, with the exception of some of the larger ones, are of volcanic origin. The coral islands themselves, although in their visible shape the work of minute polyps, are dependent upon the submarine mountains for their growth, and could not stand in the midst of the deep ocean, did not the

slope of these sunken volcanoes afford them a suitable floor on which to grow and spread.

Although all the archipelagoes which were visited by the Expedition show evident traces of volcanic action; yet the active fires are limited to a few groups, among which that of the Sandwich Islands, or the Hawaiian group, is the most remarkable. Here, again, the volcanic activity seems to be concentrated on one island, that of Hawaii, which has, at the same time, the highest mountains; especially those well-known summits, Mount Kea and Mount Loa, the first of which, according to the measurements of the Expedition, is 13,950 feet in height, and the latter 13,760 feet. The laws of volcanic action were here studied with care by Mr. Dana, and his observations are of great importance, as adding to our knowledge of the nature of this class of phenomena.

The active volcanoes on Hawaii are Loa and Hualalai, no tradition being preserved of any eruption of Mount Kea. The first mentioned of these has, besides its summit crater, another, not less remarkable, vent, Pele or Kilauea, situated at a height of 3,970 feet. Its appearance is thus described by Mr. Dana.

"Kilauea is a deep pit in the sides of Mount Loa. The gentle slopes of the dome in this part scarcely vary from a plain, and the crater appears like a vast gulf, excavated out of the rock-built structure. Although there is no cone, the country around is slightly raised above the general level, as if by former eruptions over the surface; but this is hardly apparent without extended and careful examination."

"The traveller perceives his approach to the crater in a few small clouds of steam rising from fissures not far from his path. While gazing for a second indication, he stands, unexpectedly, upon the brink of the pit. A vast amphitheatre, seven and a half miles in circuit, has opened to view. Beneath a gray, rocky precipice of 650 feet, forming the bold contour, a narrow plain of hardened lava, (the 'black ledge,') extends like a vast gallery around the whole interior. Within this gallery, below another similar precipice of 340 feet, lies the bottom, a wide plain of bare rock, more than two miles in length."

In the bottom of this extraordinary pit-like crater, nothing was to be seen but a few pools, in which the blood-red lava was seen boiling and throwing out jets of liquid matter. One of these pools, although, when compared with the whole

crater, of insignificant size, was found to measure 1,500 feet in diameter. The scene at night is described as one of indescribable sublimity.

"We were encamped on the edge of the crater, with the fires full in view. The large caldron, in the place of its bloody glare, now glowed with intense brilliancy, and the surface sparkled with shifting points of dazzling light, occasioned by the jets in constant play. A row of small basins on the southeast side of the lake were also jetting out their glowing lavas. The broad canopy of clouds above the pit, which seemed to rest on a column of wreaths and curling heaps of lighted vapor, and the amphitheatre of rocks around the lower depths, were brilliantly illuminated from the boiling lavas, while a lurid red tinged the distant parts of the inclosing walls, and threw into deeper shades of darkness the many cavernous recesses. And over this scene of restless fires and fiery vapors, the heavens, by contrast, seemed unnaturally black, with only here and there a star like a dim point of light."

Among the peculiarities of Kilauea, Mr. Dana calls attention to the striking fact of the absence of cinder cones and fragmentary accumulations around the crater; a characteristic difference between this volcano and those hitherto chiefly studied by the geological observer. Etna, Vesuvius, and the South American volcanoes, for instance, are surrounded by a rim of ejected materials, forming a cone, which commonly crumbles down at every great eruption, often changing entirely the appearance of the crater. In the Hawaiian volcanoes, on the contrary, there is very little of the conical shape generally supposed to belong, by necessity, to a volcano. Mount Loa and Mount Kea both rise with gentle and regular slopes of from 5 to 7 degrees, 6° 30′ being the average inclination of Mount Loa, and form great flattened domes, in which the craters are sunk like immense pits.

The absence of cinder cones in these volcanoes is ascribed by Mr. Dana to their more quiet action. To form cinder and scoriæ, the lava must be thrown up to a sufficient height to cool before it falls. Thus, at Vesuvius, cinder is said to be thrown up sometimes to the height of 10,000 feet; and it not uncommonly rises to 1,000 feet, even during the periods of comparative repose. In the lava pools of Kilauea, on the contrary, it appears that the most violent jets do not rise

higher than 60 feet. The ejected matter has not, therefore, time to cool, and, being still fluid when it reaches the bottom, hardens into solid lava instead of forming scoriæ. This interesting fact, that the Hawaiian volcanoes, although possessing craters of such enormous size, are so much more quiet and regular in their action, is thus explained by Mr. Dana.

"It is well known that the more free a fluid is in its motions, the more freely and with the less agitation vapors or gases escape through it. In the more viscid liquid, these rising gases become collected into large bubbles, before sufficient force is gained to break way through; and then the bubble bursts with a force approximately proportioned to its size. The rapidity of their formation will influence somewhat their violence. Increase of force is derived also from a narrow vent, which, by the adhesion of its sides to the fluid, retards the bursting till the bubble has attained a larger size than could form in an open pool; and, besides, a confined space or throat above gives far greater projectile power to the imprisoned vapors, causing, as a necessary consequence, loud reports, and often a trembling of the cone at each explosion. In this manner, the fragments of lava at Vesuvius, Stromboli, and elsewhere, are thrown to so surprising a height, and the cinder-summits of the volcanic cones are formed."

One of the most curious and striking evidences of the greater fluidity of the lava in the Hawaiian volcanoes is the formation of capillary volcanic glass, which goes by the name of Pele's hair, since it is found most abundantly around the crater of Pele, or Kilauea, where it covers the ground to the leeward of the crater, lying in parallel threads, like new-mown grass. This beautiful substance is formed by the action of the wind on the jets of melted lava thrown up from the boiling pools; it bears off small points of the fluid substance, and draws them out into silky fibres. The heavier end gradually sinks, and the wind carries over the lighter capillary extremity.

As a natural consequence of this greater fluidity, we must consider the quiet mode of eruption which is peculiar to the Hawaiian volcanoes. It is, perhaps, difficult to conceive of a great volcanic eruption without noise and earthquakes; yet it appears that the latter are not a necessary attendant on the former. The first intimation to the inhabitants in the vicinity of Mount Loa of an eruption may be the actual presence

of the mass of lava bearing down upon them, almost without a murmur or sound.

The cause of this great fluidity of the lava of these volcanoes is either their comparatively high temperature, or their chemical composition. Farther experiments to determine the temperature of the fluid lava, and a more extended and minute series of analyses of the volcanic products of these islands are needed before this question can be settled. We incline strongly, however, to the belief that a careful study of the mineralogical and chemical character of the lava of Kilauea will show that the ingredients are so combined as to form, when fused, a highly liquid slag. The entire absence of alumina in several of the varieties examined by Mr. Silliman, as well as the presence of a very large amount of soda, would seem to indicate a very different composition from that of the products of Vesuvius, Hecla, and other well-known volcanoes.

The origin of the eruptions is considered to be the formation of vapor, which, being generated within the volcanic conduit, expands the molten lava and forces it upwards, till it escapes, just as the liquid flies from the opening of a bottle of soda-water. The origin of the vapor has generally been supposed to be the water of the ocean, which finds access to the heated lava; and the circumstance that most volcanoes are situated in the vicinity of the sea, either on islands or near the shores of the continents, is generally adduced as a proof of the correctness of this theory. Mr. Dana, however, thinks that there is reason for attributing a large part, if not the whole, of the action of water to points near the surface, — in fact, to the fresh waters of the land. In making this assumption, he relies strongly on the highly important fact, "that there is no sympathy between the action of Kilauea and the summit crater of Mount Loa, situated 10,000 feet higher, thus showing that their conduits are separately operated on." Moreover, the different pools in the crater of Kilauea do not act in unison with each other, since the lava may rise and overflow in one, while it sinks a hundred feet in another; and eruptions even take place over the top of the walls of the crater, six hundred feet above its floor. As a proof that it is not necessary to call in the aid of the water of the ocean, Mr. Dana remarks

that fresh water is always found on boring near the sea-shore, and at no great depth. On a coral island, for instance, it is not necessary to dig more than ten feet, at a distance of a hundred yards from the beach, before finding water. Nearly all the water which falls as rain, and that which is produced by melting snow, is absorbed by the porous rocks; and, according to Mr. Dana's views, it finds its way to the ignited matter below.

We must confess some hesitation in adopting so small and insignificant a cause of so gigantic a phenomenon as the eruptions of the Hawaiian volcanoes, especially when we consider the limited area of the land itself. To ascribe the eruptions to the surface water, is to make them dependent in some considerable degree upon atmospheric changes; and we should naturally expect to find some relation between the action of meteorological and volcanic phenomena; for instance, an increased activity of the volcano during the rainy season, or freedom from eruptive action in regions where no rain falls; which, as far as we know, has never yet been pointed out. On the other hand, we fully recognize the many difficulties which present themselves in whatever light we attempt to look at the phenomena of volcanic action, and acknowledge the weight of the objections to the theory of Bischof and others, that the great agent is the access of the waters of the ocean to the central fires of the globe. We believe, however, that Mr. Dana does not sufficiently consider the nature and amount of the gases which must be generated within the ignited interior of the earth, and perhaps even in the conduit of the volcano itself, and which are poured out in such immense quantities by volcanoes, both during eruptions and in periods of comparative repose. In the present state of our theoretical knowledge with regard to these phenomena, the facts developed by Mr. Dana are of high importance, and they must be allowed their full weight in the decision of the many important questions connected with this interesting subject.

In conformity with the principle just discussed, Mr. Dana repels the idea that volcanoes are in any respect safety-valves for the region where they are situated, on the ground that an action so deep-seated as that of the earthquake could never find relief in the narrow channels of a volcano. The two

craters of Mount Loa are presented as arguments in favor of this view. They are but a few miles apart; the one, as before remarked, being at a height of 3,970 feet, the other, at the summit, at a height of 13,760 feet; and yet Kilauea, in spite of its immense size, does not prevent the lava from being thrown out at a height of 10,000 feet above.

"If lava may be ejected from the very lip of Kilauea, 1,000 feet above its bottom, while the pools are still boiling below, Kilauea, notwithstanding its extent, the size of its great lakes of lava, and the freedom of the incessant ebullition, is not a safety-valve that can protect even its own immediate vicinity. How, then, with so limited a protecting influence, can it relieve from danger a neighboring island? Nothing can be farther from the truth, however popular the opinion, or however supported by authority. Volcanoes are, in fact, indexes of danger, and the absence of them is the best security. They point out those portions of the globe which are most subject to earthquakes, and are the results of the same causes that render a country liable to such convulsions."

We agree entirely with Mr. Dana, that volcanoes are indexes of danger; but the instances are so numerous in which a long series of earthquakes has been suddenly stopped by an eruption of a neighboring volcano; or, *vice versa*, the cessation of volcanic action has been the signal for the commencement of subterranean convulsions, that we cannot but consider the idea of *safety-valves*, which has come down to us from the time of Strabo, and which even the South American Indians, as well as the most illustrious physicists, have recognized, as founded in nature, though there may be some apparent exceptions to the rule.

As to the first origin of the volcanoes of the Pacific, there can be little doubt, from their position with regard to each other, that they were occasioned by fissures along certain lines, indicated by the direction of the different archipelagoes. We have already alluded to the fact, that the coral islands are nothing but sunken mountain chains. In this view, the many volcanoes, either extinct or active, are to be considered as vents through which the lava continued to boil up, after it had ceased to flow from the fissures themselves. The consequence of such a continued ebullition will necessarily be, to widen the boiling pool and to give it a circular form. It will become surrounded by a rim of compact lava, cinder, or

tufa, and a cone will gradually be formed, of which the angle of inclination varies with the different circumstances under which ejections take place. The cone, small at first, goes on gradually increasing by overflowings from the summit, and by the intrusion of wedge-like masses into the ruptured sides, till at last it becomes a mountain. With regard to the rapidity of formation of lava cones, Mr. Dana remarks that it would require one hundred and sixty such eruptions as that of Mount Loa in 1840, to cover that mountain with a layer of twelve feet in thickness; and from this fact, he computes that, allowing the eruptions always to have taken place with the same frequency as now, a period of 400,000 years would be required for the formation of that part of the mountain which stands above the sea.

From his examination of the volcanic action of the Pacific, Mr. Dana infers this to be the normal method of the formation of volcanoes, thus rejecting the *elevation*-theory of Von Buch, which had been very generally adopted; and he enters somewhat in detail into the consideration of the circumstances which seem to him to indicate that the general application of that theory to the formation of volcanic mountain cannot be sustained by facts. We cannot here enter into a discussion of the subject, on which so much has already been written by the most distinguished geologists. Eminent observers having arrived at very different conclusions, after a careful examination of the same volcanic region, it seems hardly reasonable, at present, to look for unanimity of opinion on any theory. With what patience and care has the structure of Etna been investigated, and how discordant are the theoretical opinions which have been formed upon the subject! Messrs. Dufrenoy and Elie de Beaumont, in a series of elaborate memoirs upon the structure of this volcano, have advocated the views of Von Buch, while Mr. Lyell and M. Constant Prévost have arrived at conclusions diametrically opposed to the elevation theory. And recently, Professor Von Waltershausen, who has devoted eight years to the most detailed examination of this one volcano, who has given to the world as the result of his labors a work unrivalled for elaborateness of detail and beauty of execution, and who, to complete his researches, even made a journey to Iceland, in order to examine the volcanic phenomena there

displayed on so grand a scale, has declared to the French Academy, that "his views with regard to the formation and structure of volcanoes, and especially the theory of elevation, coincide in all essential points with those of M. de Beaumont." This opinion, based, as it is, on so minute and conscientious an examination, we cannot but regard as entitled to great weight. While, therefore, we coincide with Mr. Dana in his views as to the possibility of the formation of a volcanic mountain by successive overflows, and without the aid of an elevatory force acting from beneath, we must regard the accumulation of evidence on which the theory of Von Buch is supported as too great to be so easily set aside as it is in this volume. That Von Buch may have erred in the application of his theory to explain the detailed structure of localities which he had never visited, and may, as is his wont, have indulged in too sweeping generalizations, we are not disposed to deny; but that his views have a sound and philosophical basis, and are strongly supported by mathematical reasoning, seems to us clear and undeniable.

It is a fact well worthy of notice, that the Pacific, so remarkable for the number and size of its volcanoes, (most of which, however, are now extinct, and which must have been in former times the seat of unparalleled volcanic activity, should at the same time exhibit the greatest amount of subsidence. The question as to the bearing of the phenomena of volcanic action and subsidence upon each other is one of great interest, and the attempt to solve the problem forms one of the most interesting chapters in the work before us. Mr. Dana starts from the idea, now so generally adopted by geologists, and which forms, in fact, the basis of all geological science, that our globe was once in a state of igneous fluidity, the exterior of which, by gradual refrigeration, has become a solid crust. This crust, as the cooling process goes on, tends constantly to contract, and to be drawn towards the centre of the globe; — a tendency which is constantly opposed by the rigidity of the newly formed crust. The result of this struggle between two opposing forces is to produce fractures and displacements of the hardened crust, the position of which will depend on the rate of cooling of the different parts of the sphere. Suppose now, that, from some cause or other, certain portions of the earth's surface should cool before

others; they would, being thicker, resist more effectually the contracting tendency; while those regions which cooled more slowly would, from their comparative thinness, give way more readily, and at the same time be more exposed to the convulsions occasioned by the internal fires. In other words, they would be at the same time the areas of subsidence and of volcanic activity. Now, it is shown with great force by Mr. Dana, that the interior of the continents must have been, at a very early period in the geological history of the globe, free from volcanic action. Throughout the whole interior of America, we find hardly any evidence of such action; at least, none since the epoch of the deposition of the New Red Sandstone. The volcanoes are, almost without exception, situated along the coasts or on islands. If we look, for instance, at the Pacific, we find that almost every island bears the marks of volcanic agencies. The same may be said of the Atlantic, since the Azores, Cape Verde, and Canary islands are all volcanic. It may, therefore, be fairly assumed from these premises, that the actual continents, or higher parts of the earth's surface, represent those portions of our globe which cooled first; while the intermediate portions, which cooled less rapidly, exhibit the greatest amount of subsidence; just as a lead or iron ball is often found to have its surface depressed on the side which cooled last. Strictly speaking, it is not correct to say that the continents have been elevated; they are negative elevations, or those portions which have been less depressed than others. These depressions are, of course, the reservoir of the oceanic water, and, according to Mr. Dana's views, must have been so from the beginning.

It has been abundantly proved by the observations of Messrs. Darwin and Dana, that there has been a subsidence in the Pacific to the amount of several thousand feet. If this subsidence was gradual, as these investigations would lead us to believe, it follows, as a necessary consequence, that the elevation of the continents was also gradual, and not the result of a series of paroxysmal movements. Indeed, a section through any one of the continents will show, that, from the beginning, the amount of dry land has been increasing, although oscillations have taken place, in consequence of which, regions previously dry have been submerged again;

these, however, have not affected the general result. If we admit a gradual deepening of the oceanic basin, it follows that the area of dry land was less extensive when the water was shallower; since we have no reason to suppose that there has been any considerable change in the volume of the oceanic waters. The increase of the dry land is proved, beyond a doubt, by the investigation of geologists all over the world; and to account for it, it is not necessary to assume that the great depressions of the ocean have changed their places, or that continents have suddenly sunk.

Assuming, with Mr. Dana, that the oceanic basins are the regions of greatest contraction, we are naturally led to the inference, that the process of deepening is still in progress, and must go on as long as the contraction of the globe continues. Thus a continuous tension has been kept up from all time, the immediate consequence of which has been to cause fractures throughout the subsiding area. At the same time, it is evident that the disrupting and elevating force would produce the most marked effects on the borders of the region undergoing depression, where the tension would act with the greatest mechanical advantage, and an immense lateral pressure would be exerted. Now, we have only to look at the borders of the continents, to become satisfied that these very effects have taken place.

"Foldings, dislocations, and lofty elevations are common in the vicinity of the oceans, and make a crimpled border to the great oceanic basins. The volcanoes of the globe extend in lines generally along the same region, and metamorphic and volcanic action have often been most rife on the oceanic side of the lofty mountain elevations bordering the sea. Illustrations of this fact have been pointed to in North America, whose interior is, to a great extent, a region of scarcely disturbed stratification, while on one side rise the Rocky Mountains, a lofty border to the Pacific, and on the other, the Appalachians, a corresponding border to the Atlantic; and the volcanoes of the former region, as well as the metamorphic changes and foldings of the latter, are on the *oceanic* side of the mountains; moreover, the direction and steeper west than east slopes of the Appalachian folds are just what lateral action over the Atlantic should produce. The Andes also have their volcanic action and principal dislocations on the side towards the neighboring ocean. We observe, too, that the largest ocean, the Pacific, is encircled by volcanoes, the

lines extending from New Zealand, by the Philippines, Japan, and Kamschatka, around by the Aleutian archipelago to Northwest America, and south by the Andes to Terra del Fuego; and recent discoveries have shown that Deception island is not the only volcanic region on the southern border of this ocean."

In thus connecting the elevation of mountain chains with the subsidence of the great oceanic areas, Mr. Dana has presented an entirely new view of the architecture of the globe, and one which, by the magnitude of its generalizations, and by the strong array of facts by which it is supported, commends itself to the attention of every geologist. In connection with this subject, we would further call the attention of the reader to another important chapter in the work, entitled "General Arrangement of Land in the Pacific." The views here laid down are, as far as we know, entirely new, and are deduced chiefly from the author's own observations. It is shown, first, that the islands of the Pacific are arranged in lines, and this arrangement, (which is very conspicuous on the chart accompanying the volume,) is ascribed to the opening of fissures during the subsidence of that region. From the very nature of the earth's crust, which is a brittle material of unequal thickness, and by no means of uniform texture, it is not to be expected that such ruptures should be continuous for long distances; and Mr. Dana shows, from a number of examples, that they usually consist of a series of rents, which are often largest at one extremity. These fissures are not arranged in straight lines, but in advancing and receding series, so as to give rise to distinct curves, of which many striking instances are pointed out in the various island groups of the Pacific, and the adjacent continents. Thus it is shown, that the great central chain of the Pacific islands, 6,000 miles long, represents a simple curvature, the convex side of which is towards the southwest. The Aleutian archipelago, 600 miles in length, has a strong convexity towards the ocean. So, too, in eastern Asia, the courses of the mountain chains, as well as the coast-lines, are convex towards the Pacific. But Mr. Dana carries his generalizations still farther, and endeavors to trace, over the entire surface of the globe, two great systems of trend of the lines of coasts as well as of islands, which are nearly at right angles to each other; and on these, he conceives that the

forms of continents are mainly dependent. Our limits do not allow us to go into the details of the facts which are adduced in support of these bold generalizations; but it must be confessed, that the instances of parallelism with one or the other of the two systems, the northeastern or the northwestern, are numerous and striking. The cause of this simplicity and uniformity of arrangement of the great features of the globe is sought for by Mr. Dana in the distribution of the lines of equal magnetic intensity, and in their agreement with those of equal heating or cooling, which together would originate a crystalline structure in the gradually consolidating crust of the globe, producing lines of easy fracture or cleavage, according to the arrangement of the mineral ingredients of the crystalline rocks.

This conformity in the direction of the principal lines of coast and of mountain chains, both continental and submarine, does not by any means imply the contemporaneous elevation of parallel chains, or that they are referable to the same epoch. On the contrary, the very cause to which they are referred leads directly to the inference, that they have, in part, a very remote origin. Indeed, if the areas of subsidence exert a lateral tension, then this force must have been acting from all times; and whenever this tension has been overcome, new lines of fracture have been caused and new mountains raised. The violence of the disruption and the amount of elevation would be in proportion to the resistance opposed by the continental masses. And here we have a clue to the fact, that the most recent mountain chains are the most elevated, having been raised at a period when the earth's crust was consolidated to a greater depth, and therefore capable of greater resistance.

At the close of the chapter in which these subjects are discussed, Mr. Dana remarks "that the reader will not fail to observe that the facts, as well as principles deduced, accord in no respect with the hypothesis of M. Elie de Beaumont, that the direction of a mountain chain is an index of its age." We must confess that this seems rather a rude throwing down of the gauntlet to the great champion of the parallelism of mountain chains of the same geological age; and while we would not detract from the merit of the brilliant generalizations, and the ingenuity with which they are sup-

ported by our author, we would suggest that it is more easy to sketch out a theory in this department, than it is to place it on a basis of mathematical certainty. Let any one examine the various theories which have been framed to explain the physical structure of the surface of the globe; let him read the elaborate attempts of Sickler, Boucheporn, Pissis, Hauslab, and others, to reduce this class of phenomena to some great general principle; and he will see how, starting from principles widely different, they have been able to support their peculiar views by such an amount of evidence as to astonish, and perhaps even to convince, the superficial examiner. He will be obliged to confess that the theorist in this department of geology has a dangerous and seductive field opened before him, in the investigation of which he must proceed with caution. It is from this point of view that we look with the highest respect on the labors of M. de Beaumont, who has devoted so many years to the collection of facts and the arranging of them upon a mathematical basis, till a mass of evidence has accumulated under his hands, which begins to weigh with almost irresistible force. The fact that M. de Beaumont's views, in spite of the searching scrutiny to which they have been subjected, have been gradually extending themselves among geologists, in some instances almost against their will, shows that there must be some truth at the bottom of the idea of the parallelism of contemporaneous elevations, even if it should prove to be more limited in its application than recent investigations seem to indicate.

From the archipelagoes of the Pacific, we pass to the Australian continent and the surrounding islands. The geological character of New South Wales seems to be monotonous in the extreme. The prevailing rock is a kind of sandstone, which occurs, apparently, over a large portion of New Holland, and which, in connection with the situation of this semi-continent, as Mr. Dana calls it, within the desert latitudes of the globe, renders the soil peculiarly dry, and the whole appearance of the country in the highest degree uninviting. This sandstone is associated with coal, the working of which, however, seems thus far to have been attended with some difficulty, owing to the softness of the rocks. A large quantity of organic remains have been found in this

coal, although the number of species is comparatively small. With the exception of a single fossil fish, they all belong to the vegetable kingdom; but it is remarkable, that, among them, there are found but few of the arborescent ferns which characterize the carboniferous strata of Europe and North America; the prevalent species are small ferns, equisetacea, and remains of coniferæ allied to our pines.

Basalt occurs in many parts of New South Wales, and we are informed that some of the cliffs of this rock in the vicinity of Kiama will bear comparison with those of Staffa. This rock often occurs in layers which alternate with the beds of sandstone, having the same dip and bearing with them, thus showing conclusively that they are formed by the overflowing of the igneous rock while in a state of fusion, before the overlying strata of sandstone were deposited, and not as the result of intrusion.

From Australia, after giving a glance at the geology of the Philippines, the Sooloo islands, Deception island, and Madeira, all of which are of volcanic origin, our author proceeds to the western coast of South America. Here his attention was especially turned to the granitic rocks; and those especially interested in the study of this class of rocks will find in this part of the work a valuable addition to our knowledge of the structure of the granite of the Andes, and its passage into the manifold varieties of sienite, porphyry, and other allied rocks, as also of the structure and origin of veins in these rocks.

The coast of Peru is lined by a formation of argillaceous sandstone, which our author refers to the Oolitic period. From his observations, as well as those of D'Aubigny and Tschudi, it seems that this portion of the secondary formation, which is so scantily represented in North America, occupies a considerable area in the southern half of the American continent.

We would also mention the occurrence, in the vicinity of Callao, and on the neighboring island of San Lorenzo, of a layer of recent shells, some four or five feet in thickness, and about eighty feet above the sea. Darwin, by whom this fact was first observed, considered it of importance, as indicating a recent elevation of the coast. Mr. Dana, however, is inclined to consider these shells as affording no positive proof

of such an elevation, since they are not deposited in regular layers, but merely spread out just beneath the soil. He supposes that they were carried to their present situation by the natives, which supposition is confirmed by the fact that Peruvian ware, thread, &c., are found among them. The idea is thus very naturally suggested, that heaps and beds of shells in the neighborhood of the sea may often have owed their elevated position to human hands rather than to any elevation of the soil on which they are found, and that too careful an examination of such supposed cases of upheaval cannot be made, before referring them to this cause.

The concluding chapters of Mr. Dana's work are devoted to the description of a region which, at the time of the expedition, was but little known, though it has since become of immense importance, and a throng of emigrants are now hastening to it from every quarter of the globe. It is hardly necessary to say that we allude to Oregon and Northern California. The main features in the physical geography of the whole country on the Pacific side of the Rocky Mountains are dependent on the arrangement of the lines of mountains which stretch through the country, nearly parallel with the coast and with each other. There are three of these ranges, the Coast Range, the Cascade Range, at a distance of 150 miles inland, and the Blue Mountains, which are 350 miles from the sea, and eight or nine thousand feet in elevation. The consequence of this arrangement is to divide the country into three distinct regions, and at the same time, to give a remarkable expansion and length to its river basins.

The rocks which compose these mountain chains appear to be, almost exclusively, crystalline, being either eruptive, plutonic, or metamorphic. Granite, porphyry, sienite, &c., are of frequent occurrence; and there are also found associated with these rocks some ancient sandstones and conglomerates, the age of which has not been ascertained, since no fossils have been detected in them; but, in all probability, they belong to a very remote epoch. Basaltic and recent igneous rocks are common in Oregon, and many a frosted peak attests the former activity of volcanic fires in that region. There is but little doubt that the high peaks of the Cascade Range, such as Mounts Baker, Rainer, Hood, and

St. Helen's, once formed a line of volcanoes through the whole extent of Oregon, and far into California. Some of these are said to have shown evidence of activity within the last few years; and Col. Fremont states positively, that, on the 23d of November, 1842, ashes were ejected by St. Helen's. According to Dr. Pickering, the rocks at the base of this mountain are cellular, basaltic lavas; and similar volcanic productions are found at the foot of Mount Hood. Obsidian, a volcanic glass, is said to occur in some parts of the Shasty region; and the Shasty Indians use it for their arrow-heads, which they work with great skill.

The basalts often form a series of layers, from fifteen to fifty feet in thickness. Such beds, piled one upon another, form the palisades of the Columbia river, which are bluff, like those of the Hudson, and are about two hundred feet in height. The isolated columns, tabular summits, and mural walls of this rock give a peculiar and highly picturesque character to the scenery of the valley of the Columbia.

Among the sedimentary rocks of Oregon, may be mentioned a large deposit of tertiary shale, which occurs in various places, from Puget's Sound to San Francisco. They were first noticed in the vicinity of Astoria, where they attain a thickness of one thousand or twelve hundred feet. How far they extend into the interior has not yet been determined. From the fossils imbedded in them it was inferred, by Mr. Conrad, that they belong to the era of the Miocene, or middle tertiary. Secondary formations seem to be entirely wanting on the western slope of the Rocky Mountains.

The drift deposits of Oregon and California deserve particular notice, on account of their extent, and because they contain a vast amount of gold. Every river has its bottom-lands, which lie commonly in two separate plains, known as the upper and lower prairies. Mr. Dana has given a number of sections, illustrating the position, width, and height of these terraces along the various rivers. The most interesting are those of the Sacramento, which have become so famous from their almost fabulous supply of gold. These terraces have afforded the author an opportunity of discussing their origin, which, according to his view, must be due to one or the other of two causes; either lakes have existed along the rivers, and have burst their barriers, or else the rivers have

excavated their beds in consequence of the elevation of the country. The supposition that lakes might have been occasioned by the sudden elevation of a barrier across the river valley, is rendered somewhat plausible by the circumstance that the ranges of heights run parallel with the coast. But when we come to apply this hypothesis to the Sacramento valley, the difficulties become very obvious. The terraces occur at a distance of at least 150 miles from the sea, and they preserve, throughout this distance, nearly the same relative height above the river. The only place where a barrier could have existed is at the Caquines Straits, near the bay of San Francisco; and it would require a barrier of at least four hundred feet in height to set the water back, so as to cover the upper terrace at a distance of 150 miles above. Moreover, on the supposition that the valley was once occupied by a lake, the terrace ought to decrease gradually, and, when the river bed had reached the height of four hundred feet, die out entirely, instead of maintaining a constant height along its whole course. Mr. Dana concludes that these terraces are the proper effect of river floods, and must be taken as indicating a change of level in the country. The effect of such a rise of the land may be understood by considering the changes which would take place during the elevation of a region of alluvial flats.

"If a country rise abruptly, the river will commence to work itself to a lower level, and proceed with rapidity, ending finally in attaining the very gradual slope of ordinary rivers, a descent of one or two feet to the mile. At the same time, in the season of floods, the river would wear into the former alluvium, (now its banks,) and widen its surface; and this widening would go on at every successive freshet till the river had a new *lower* plain on its borders."

The same effect takes place, according to Mr. Dana, during a gradual rise of the land; and he considers the existence of terraces in an alluvial region as being by no means certain evidence of an *abrupt* rise of the country. We trust that a sufficient number of accurate observations on the terraces east of the Rocky Mountains will soon have accumulated, so as to allow a general survey of their connection with each other in different parts of the country to be made. We fully believe, with our author, that they point to a grand

geological phenomenon, in which the whole continent was concerned, and, that if properly studied, they would throw a new light on the most recent geological changes which have been in progress throughout the globe.

Finally, Mr. Dana calls our attention to a most striking feature of the coast of Oregon, — the complexity of its outline, and the narrow channels which cut into it to a great depth, like artificial canals, and which so strongly resemble the *fiords* of Norway, (a name which has been adopted by our author, and is applied by him to similar channels all over the world.) The fiords of the Northwest coast occur from the mouth of the Columbia to the Russian settlements in lat. 60° ; and form, in many places, an irregular net-work of canals, in which the water is very deep, — so much so, that large vessels may graze the rocky shore with their sides, without touching the bottom with their keels.

Whoever, after having coasted along the flat and monotonous shores of the German Ocean, makes his way northward to the Norwegian coast, will not fail to be struck with these narrow and intricate channels, which penetrate so deeply into the land. If at all accustomed to inquire into the causes which determine the physical outlines of a country, he will not fail to recognize, in this peculiar character of the coast line, the action of some great general cause. The same impression was made on Mr. Dana when visiting the northwest coast of this continent. It occurred to his philosophical mind, that fiords are not limited to a few coasts, but are common to the higher latitudes all over the world, while they are almost entirely wanting in the torrid and lower temperate zones. Thus, along the west coast of America, they abound to the north of 48°; and to the south, in lower Patagonia and Terra del Fuego, south of 48°, there are similar passages intersecting the land, and often cutting it into islands. But between these limits, the coast has few deep bays, and still fewer of these channel-like indentations or fiords. On the eastern coast of this continent, we observe the same general fact. To the north of the equator, the coast is singularly even in its outline, till we reach latitude 43°, when, as may be seen on a good map, fiords become very numerous on the coast of Maine, and exhibit deep and winding ramifications when we get as far north as Greenland.

The same may be said with regard to the eastern continent. The coast of Norway, so deeply indented, is a singular contrast to that of France or Spain. Southern Africa does not reach below the parallel of 35°, and has a simple outline throughout.

The origin of these fiords becomes, therefore, an interesting inquiry. There are but three causes by which they can have been formed; either they must have originated from subaqueous or subaerial denudation, or they must have been the result of rupturings of the earth's crust. After a careful discussion of the subject, Mr. Dana arrives at the conclusion that they must be the result of subaerial denudation. Indeed, we readily agree that the sea is incapable of excavating such valleys in its coasts. We need only take a trip to Kennebec or Saco bays, to be convinced that the waters within have the quietness of an inland stream, and rise and fall with the tides without commotion. These channels, therefore, are not increasing in depth by the action of the sea. If the fiords, then, are the result of subaerial denudation, it follows that the land must have been at a higher elevation above the sea when subjected to this erosion, and that the fiords were once the valleys of the land. Now, let us suppose any mountainous country to subside, till its flat, alluvial region along the coast is submerged; then its long valleys will necessarily become so many fiords. This is illustrated by reference to some of the islands of the Pacific; it is shown, by Mr. Dana, that Mangareva, one of the Gambier islands, with its long projecting points, and deep bays between, exactly resembles what Tahiti would become if submerged to the same extent.

The question how this extensive denudation was effected, whether by the agency of currents of water, or by glaciers, remains a fruitful subject of discussion. In the mean time, we agree with Mr. Dana, "that there is abundant evidence presented by the fiords, that there has taken place a change of level on our globe, which has affected many regions north of the parallel of 45° or 50°, while, south of this latitude, this change was experienced, if at all, to a less and less degree as we approach the tropics. It indicates the probable subsidence of the surface of our earth towards the higher latitudes, while, about the equator, if there has been any

corresponding change, it has been an elevation. Perhaps it is for this reason that the great chain of America is highest in the equatorial regions, and diminishes in altitude towards either pole."

We cannot avoid recognizing the intimate connection between the causes which have originated the fiords, and those to which the accumulations of the northern drift, and the attendant scratching and polishing of the rocks, are to be ascribed. The fiords are confined to those regions where the drift phenomena are most conspicuously displayed; and it seems not unreasonable to suppose that they belong to the same geological epoch, and are the result of the same great causes.

We have thus passed rapidly over Mr. Dana's book, endeavoring to lay before the reader a sketch of some of the most important topics which are discussed in it. We regard the work as eminently suggestive in its character, and abounding in theoretical views of great originality and importance. The peculiar opportunities afforded by such a voyage as that of the Exploring Expedition are such as few geologists can expect to enjoy; and we rejoice that they have been given to one so eminently fitted to derive the greatest amount of instruction from them. The results here presented are commensurate in magnitude and importance with the field in which they were obtained.

ART. IV. — *Lives of the Queens of Scotland, and English Princesses connected with the Regal Succession of Great Britain.* By AGNES STRICKLAND. Vols. I. & II. New York: Harpers. 1851. 12mo.

MISS STRICKLAND has done English literature good service by the publication of her Lives of the Queens. She has, with great industry and love, restored many old portraits from the dust and coloring of age which had long rested on them. She is no very great artist herself; but she cleans the picture, and brings out forms and features with a good deal of truth and dis-